

Claims

WHAT IS CLAIMED IS:

1. A method comprising:

selecting a modeling parameter from a plurality of modeling parameters characterizing a mixture of Student distribution components;

computing a tractable approximation of a posterior distribution for the selected modeling parameter based on an input set of data and a current estimate of a posterior distribution of at least one unselected modeling parameter in the plurality of modeling parameters;

computing a lower bound of a log marginal likelihood as a function of current estimates of the posterior distributions of the modeling parameters, the current estimates of the posterior distributions of the modeling parameters including the computed tractable approximation of the posterior distribution of the selected modeling parameter; and

generating a probability density modeling the input set of data, the probability density including the mixture of Student distribution components, the mixture of Student distribution components being characterized by the current estimates of the posterior distributions of the modeling parameters, if the lower bound is satisfactorily optimized.

2. The method of claim 1 wherein the computing operations comprise a first iteration and further comprising:

selecting a different modeling parameter from the plurality of modeling parameters and repeating in a subsequent iteration the operations of computing a

1 tractable approximation and computing a lower bound using the newly selected
2 modeling parameter, if the lower bound is not satisfactorily optimized in the first
3 iteration.

4 3. The method of claim 1 wherein computing a lower bound comprises:
5 computing the lower bound of the log marginal likelihood as a function of
6 prior distributions of the modeling parameters.

7 4. The method of claim 1 wherein computing a tractable approximation of
8 a posterior distribution comprises:

9 computing a variational approximation of the posterior distribution of the
10 selected modeling parameter.

12 5. The method of claim 1 wherein one of the plurality of modeling
13 parameters represents a mean of each of the Student distribution components.

14 6. The method of claim 1 wherein one of the plurality of modeling
15 parameters represents a precision matrix of the Student distribution components.

17 7. The method of claim 1 wherein one of the plurality of modeling
18 parameters represents a labeling parameter of the Student distribution components.

20 8. The method of claim 1 wherein one of the plurality of modeling
21 parameters represents a scaling parameter of a precision matrix of the Student
22 distribution components.

1 9. The method of claim 1 wherein one of the plurality of modeling
2 parameters represents a mixing coefficients parameter of the Student distribution
3 components.

4 10. The method of claim 1 wherein generating a probability density
5 comprises:

6 generating the probability density including the mixture of Student
7 distribution components, the mixture of Student distribution components being
8 characterized by the current estimates of the posterior distributions of the
9 modeling parameters and an estimate of the number of degrees of freedom of each
10 Student distribution component.

11 11. The method of claim 1 further comprising:

12 storing the current estimates of the posterior distributions of the modeling
13 parameters in a storage location.

14 12. The method of claim 1 wherein the input set of data represents auditory
15 speech data from an unknown number of speakers, and further comprising
16 determining a correct number of speakers from the probability density modeling
17 the input set of data.

18 13. The method of claim 1 wherein the input set of data represents image
19 segmentation data from images having regions of different characteristics.

1 14. A computer program product encoding a computer program for
2 executing on a computer system a computer process, the computer process
3 comprising:

4 selecting a modeling parameter from a plurality of modeling parameters
5 characterizing a mixture of Student distribution components;

6 computing a tractable approximation of a posterior distribution for the
7 selected modeling parameter based on an input set of data and a current estimate
8 of a posterior distribution of at least one unselected modeling parameter in the
9 plurality of modeling parameters;

10 computing a lower bound of a log marginal likelihood as a function of
11 current estimates of the posterior distributions of the modeling parameters, the
12 current estimates of the posterior distributions of the modeling parameters
13 including the computed tractable approximation of the posterior distribution of the
14 selected modeling parameter; and

15 generating a probability density modeling the input set of data, the
16 probability density including the mixture of Student distribution components , the
17 mixture of Student distribution components being characterized by the current
18 estimates of the posterior distributions of the modeling parameters, if the lower
19 bound is satisfactorily optimized.

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21 15. The computer program product of claim 14 wherein the computing
22 operations comprise a first iteration and further comprising:

23 selecting a different modeling parameter from the plurality of modeling
24 parameters and repeating in a subsequent iteration the operations of computing a
25 tractable approximation and computing a lower bound using the newly selected

1 modeling parameter, if the lower bound is not satisfactorily optimized in the first
2 iteration.

3 16. The computer program product of claim 14 wherein computing a lower
4 bound comprises:

5 computing the lower bound of the log marginal likelihood as a function of
6 prior distributions of the modeling parameters.

7 17. The computer program product of claim 14 wherein computing a
8 tractable approximation of a posterior distribution comprises:

9 computing a variational approximation of the posterior distribution of the
10 selected modeling parameter.

11 18. The computer program product of claim 14 wherein one of the plurality
12 of modeling parameters represents a mean of each of the Student distribution
13 components.

14 19. The computer program product of claim 14 wherein one of the plurality
15 of modeling parameters represents a precision matrix of the Student distribution
16 components.

17 20. The computer program product of claim 14 wherein one of the plurality
18 of modeling parameters represents a labeling parameter of the Student distribution
19 components.

20 21. The computer program product of claim 14 wherein one of the plurality
21 of modeling parameters represents a scaling parameter of a precision matrix of the
22 Student distribution components.

1 22. The computer program product of claim 14 wherein one of the plurality
2 of modeling parameters represents a mixing coefficients parameter of the Student
3 distribution components.

4 23. The computer program product of claim 14 wherein generating a
5 probability density comprises:

6 generating the probability density including the mixture of Student
7 distribution components, the mixture of Student distribution components being
8 characterized by the current estimates of the posterior distributions of the
9 modeling parameters and an estimate of the degrees of freedom of each Student
10 distribution component.

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12 24. The computer program product of claim 14 wherein the computer
13 process further comprises:

14 storing the current estimates of the posterior distributions of the modeling
15 parameters in a storage location.

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17 25. The computer program product of claim 14 wherein the input set of data
18 represents auditory speech data from an unknown number of speakers, and further
19 comprising determining a correct number of speakers from the probability density
20 modeling the input set of data.

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22 26. The computer program product of claim 14 wherein the input set of data
23 represents image segmentation data from images having regions of different
24 characteristics.

1 27. A system comprising:

2 a modeling parameter selector selecting a modeling parameter from a
3 plurality of modeling parameters characterizing a mixture of Student distribution
4 components;

5 a tractable approximation module computing a tractable approximation of a
6 posterior distribution for the selected modeling parameter based on an input set of
7 data and a current estimate of a posterior distribution of at least one unselected
8 modeling parameter in the plurality of modeling parameters;

9 a lower bound optimizer module computing a lower bound of a log
10 marginal likelihood as a function of current estimates of the posterior distributions
11 of the modeling parameters, the current estimates of the posterior distributions of
12 the modeling parameters including the computed tractable approximation of the
13 posterior distribution of the selected modeling parameter; and

14 a data model generator generating a probability density modeling the input
15 set of data, the probability density including the mixture of Student distribution
16 components, the mixture of Student distribution components being characterized
17 by the current estimates of the posterior distributions of the modeling parameters,
18 if the lower bound is satisfactorily optimized.

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20 28. The system of claim 27 wherein the lower bound optimizer computes
21 the lower bound of the log marginal likelihood as a function of prior distributions
22 of the modeling parameters.

1 29. The system of claim 27 wherein the tractable approximation module
2 computes a variational approximation of the posterior distribution of the selected
3 modeling parameter.

4 30. The system of claim 27 wherein one of the plurality of modeling
5 parameters represents a mean of each of the Student distribution components.

6 31. The system of claim 27 wherein one of the plurality of modeling
7 parameters represents a precision matrix of the Student distribution components.

8 32. The system of claim 27 wherein one of the plurality of modeling
9 parameters represents a labeling parameter of the Student distribution components.

10 33. The system of claim 27 wherein one of the plurality of modeling
11 parameters represents a scaling parameter of a precision matrix of the Student
12 distribution components.

13 34. The system of claim 27 wherein one of the plurality of modeling
14 parameters represents a mixing coefficients parameter of the Student distribution
15 components.

16 35. The system of claim 27 wherein the data model generator generates the
17 probability density including the mixture of Student distribution components, the
18 mixture of Student distribution components being characterized by the current
19 estimates of the posterior distributions of the modeling parameters and an estimate
20 of the degrees of freedom of each Student distribution component.

1 36. The system of claim 27 further comprising:

2 a memory storing the current estimates of the posterior distributions of the
3 modeling parameters.

4 37. The system of claim 27 wherein the input set of data represents auditory
5 speech data from an unknown number of speakers, and further comprising
6 determining a correct number of speakers from the probability density modeling
7 the input set of data.

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9 38. The system of claim 27 wherein the input set of data represents image
10 segmentation data from images having regions of different characteristics.

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1 39. A method comprising:

2 computing a tractable approximation of a posterior distribution for a
3 selected modeling parameter of a plurality of modeling parameters characterizing
4 a mixture of Student distribution components based on an input set of data and a
5 current estimate of a posterior distribution of at least one unselected modeling
6 parameter in the plurality of modeling parameters;

7 determining whether current estimates of the posterior distributions of the
8 modeling parameters are satisfactorily optimized, the current estimates of the
9 posterior distributions of the modeling parameters including the computed
10 tractable approximation of the posterior distribution of the selected modeling
11 parameter; and

12 modeling the input set of data by the mixture of Student distribution
13 components, the mixture of Student distribution components being characterized
14 by the current estimates of the posterior distributions of the modeling parameters.

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16 40. The method of claim 39 wherein the computing operation and
17 determining operation comprise a first iteration and further comprising:

18 selecting a different modeling parameter from the plurality of modeling
19 parameters and repeating in a subsequent iteration the operations of computing a
20 tractable approximation and computing a lower bound using the newly selected
21 modeling parameter, if the lower bound is not satisfactorily optimized in the first
22 iteration.

1 41. The method of claim 39 wherein the operation of determining whether
2 current estimates of the posterior distributions of the modeling parameters are
3 satisfactorily optimized comprises:

4 computing a lower bound of the log marginal likelihood as a function of
5 prior distributions of the modeling parameters and a variational posterior
6 distribution; and

7 determining whether the lower bound satisfies a predetermined criterion of
8 the selected modeling parameter.

9 42. The method of claim 39 wherein computing a tractable approximation
10 of a posterior distribution comprises:

11 computing a variational approximation of the posterior distribution.

12 43. The method of claim 39 wherein one of the plurality of modeling
13 parameters represents a mean of each of the Student distribution components.

14 44. The method of claim 39 wherein one of the plurality of modeling
15 parameters represents a precision matrix of the Student distribution components.

16 45. The method of claim 39 wherein one of the plurality of modeling
17 parameters represents a labeling parameter of the Student distribution components.

18 46. The method of claim 39 wherein one of the plurality of modeling
19 parameters represents a scaling parameter of a precision matrix of the Student
20 distribution components.

1 47. The method of claim 39 wherein one of the plurality of modeling
2 parameters represents a mixing coefficients parameter of the Student distribution
3 components.

4 48. The method of claim 39 wherein modeling the input data comprises:
5 generating the probability density including the mixture of Student
6 distribution components, the mixture of Student distribution components being
7 characterized by the current estimates of the posterior distributions of the
8 modeling parameters and an estimate of the degrees of freedom of each Student
9 distribution component.

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11 49. The method of claim 39 further comprising:
12 storing the current estimates of the posterior distributions of the modeling
13 parameters in a storage location.

1 50. A computer program product encoding a computer program for
2 executing on a computer system a computer process, the computer process
3 comprising:

4 computing a tractable approximation of a posterior distribution for a
5 selected modeling parameter of a plurality of modeling parameters characterizing
6 a mixture of Student distribution components based on an input set of data and a
7 current estimate of a posterior distribution of at least one unselected modeling
8 parameter in the plurality of modeling parameters;

9 determining whether current estimates of the posterior distributions of the
10 modeling parameters are satisfactorily optimized, the current estimates of the
11 posterior distributions of the modeling parameters including the computed
12 tractable approximation of the posterior distribution of the selected modeling
13 parameter; and

14 modeling the input set of data by the mixture of Student distribution
15 components, the mixture of Student distribution components being characterized
16 by the current estimates of the posterior distributions of the modeling parameters.

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18 51. The computer program product of claim 50 wherein the computing
19 operation and determining operation comprise a first iteration and further
20 comprising:

21 selecting a different modeling parameter from the plurality of modeling
22 parameters and repeating in a subsequent iteration the operations of computing a
23 tractable approximation and computing a lower bound using the newly selected
24 modeling parameter, if the lower bound is not satisfactorily optimized in the first
25 iteration.

1 52. The computer program product of claim 50 wherein the operation of
2 determining whether current estimates of the posterior distributions of the
3 modeling parameters are satisfactorily optimized comprises:

4 computing a lower bound of the log marginal likelihood as a function of
5 prior distributions of the modeling parameters and a variational posterior
6 distribution; and

7 determining whether the lower bound satisfies a predetermined criterion.

8 53. The computer program product of claim 50 wherein computing a
9 tractable approximation of a posterior distribution comprises:

10 computing a variational approximation of the posterior distribution of the
11 selected modeling parameter.

12 54. The computer program product of claim 50 wherein one of the plurality
13 of modeling parameters represents a mean of each of the Student distribution
14 components.

16 55. The computer program product of claim 50 wherein one of the plurality
17 of modeling parameters represents a precision matrix of the Student distribution
18 components.

20 56. The computer program product of claim 50 wherein one of the plurality
21 of modeling parameters represents a labeling parameter of the Student distribution
22 components.

1 57. The computer program product of claim 50 wherein one of the plurality
2 of modeling parameters represents a scaling parameter of a precision matrix of the
3 Student distribution components.

4 58. The computer program product of claim 50 wherein one of the plurality
5 of modeling parameters represents a mixing coefficients parameter of the Student
6 distribution components.

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8 59. The computer program product of claim 50 wherein modeling the input
9 data comprises:

10 generating the probability density including the mixture of Student
11 distribution components, the mixture of Student distribution components being
12 characterized by the current estimates of the posterior distributions of the
13 modeling parameters and an estimate of the degrees of freedom of each Student
14 distribution component.

15 60. The computer program product of claim 50 wherein the computer
16 process further comprises:

17 storing the current estimates of the posterior distributions of the modeling
18 parameters in a storage location.

1 61. A system comprising:

2 a tractable approximation module computing a tractable approximation of a
3 posterior distribution for a selected modeling parameter of a plurality of modeling
4 parameters characterizing a mixture of Student distribution components based on
5 an input set of data and a current estimate of a posterior distribution of at least one
6 unselected modeling parameter in the plurality of modeling parameters;

7 an optimizer module determining whether current estimates of the posterior
8 distributions of the modeling parameters are satisfactorily optimized, the current
9 estimates of the posterior distributions of the modeling parameters including the
10 computed tractable approximation of the posterior distribution of the selected
11 modeling parameter; and

12 a data model generator modeling the input set of data by the mixture of
13 Student distribution components, the mixture of Student distribution components
14 being characterized by the current estimates of the posterior distributions of the
15 modeling parameters.

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17 62. The system of claim 61 wherein optimizer module computes a lower
18 bound of the log marginal likelihood as a function of prior distributions of the
19 modeling parameters and a variational posterior distribution, and determines
20 whether the lower bound satisfies a predetermined criterion.

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22 63. The system of claim 61 wherein the tractable approximation modules
23 computes a variational approximation of the posterior distribution of the selected
24 modeling parameter.

1 64. The system of claim 61 wherein one of the plurality of modeling
2 parameters represents a mean of each of the Student distribution components.

3 65. The system of claim 61 wherein one of the plurality of modeling
4 parameters represents a precision matrix of the Student distribution components.
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6 66. The system of claim 61 wherein one of the plurality of modeling
7 parameters represents a labeling parameter of the Student distribution components.
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9 67. The system of claim 61 wherein one of the plurality of modeling
10 parameters represents a scaling parameter of a precision matrix of the Student
distribution components.
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12 68. The system of claim 61 wherein one of the plurality of modeling
13 parameters represents a mixing coefficients parameter of the Student distribution
components.
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15 69. The system of claim 61 wherein modeling the input data comprises:
16 generating the probability density including the mixture of Student
17 distribution components, the mixture of Student distribution components being
18 characterized by the current estimates of the posterior distributions of the
19 modeling parameters and an estimate of the degrees of freedom of each Student
20 distribution component.
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22 70. The system of claim 61 further comprising:
23 a memory storing the current estimates of the posterior distributions of the
modeling parameters.
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